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ABSTRACT

The paper will examine the role of technological tools, especially computers, as facilitators and non-facilitators in problem-solving in mathematics education. Examples of problem tasks will be given in each case. The paper will focus on over-generalizations made regarding the power of technology in mathematical problem solving. These over generalizations (which I shall label as myths) will be illustrated by problem tasks and results of the studies that were conducted at the American University of Beirut on mathematical problem solving in schools and out-of school by students and practitioners. The possible long-term effects of technology on problem solving in non-academic contexts are identified and discussed. (Author)

Technology and Problem Solving in Mathematics: Myths and Reality.

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The paper will examine the role of technological tools, especially computers, as facilitators and non-facilitators in problem solving in mathematics education. Examples of problem tasks will be given in each case. The paper will focus on over-generalizations made regarding the power of technology in mathematical problem solving. These over-generalizations (which I shall label as myths) will be illustrated by problem tasks and results of the studies that were conducted at the American University of Beirut on mathematical problem solving in schools and out-of school by students and practitioners. The possible long-term effects of technology on problem solving in non-academic contexts will be identified and discussed.

Technology is often defined as making or using of tools and artifacts. The statement attributed to Benjamin Franklin seems to imply that humans are technological animals. Are humans the only technological animals? Apes use tools with ease and skill and apes may learn the use of a tool from each other by observation and imitation. Why is it, then, that humans have advanced technologically in a dramatic way during the last ten thousand years and apes are technologically still where they were? The answer probably lies in our conception of tools and what they mean.

Tools are normally seen as those material (physical) instruments that act on objects in the external world thus changing them. (Vygotski, 1997) has introduced the concept of symbolic tools which do not act on objects but are rather psychological means of influencing the behavior of one's own or of others. Examples of symbolic tools include language, systems of counting, mnemonic techniques, mathematical symbol systems, and maps.

White (1959) hypothesizes that the ability to symbol is what distinguishes humans from sub- humans. Humans have the ability to originate and bestow meaning upon a thing or event *and* the ability to grasp and appreciate such meaning. Thus, humans have religions, arts, sciences, whereas, sub- humans do not have the ability to generate such meanings. In humans, articulate speech is the most characteristic form of expression of the ability to symbol. Because of this ability, humans can preserve their meanings in the form of symbols (language, mathematical systems, arts…), thus new generations start where previous generations have finished. Lacking this ability, each generation of sub-humans has to start anew. This probably explains why humans have progressed so much technologically while apes have not.

Human culture may be seen as the accumulation of the products of humans exercising their unique ability to symbol. White (1959) identifies four inter-connected components of human culture:

- *ideological*: beliefs, values, philosophies
- *sociological* : customs, institutions, rules and patterns of interpersonal behavior

- *sentimental*: feelings (interpersonal) and attitudes
- *technological*: use and making of tools plus ability to accumulate and progress through the symbolic faculty

Theory of Technological Determination

White (1959) advances the thesis that the technological component of culture determines the form and content of the social, philosophic, and sentimental components. Social change has historically tended to follow technological changes. In any age, the technological systems that were developed to ensure and sustain means of subsistence and protection from the elements and enemies have shaped the form and content of social organizations. The social organizations, together with the technology, determine to a large extent, the value system as well as beliefs and attitudes. It is not very difficult to see how technologies of production and defense in the last two centuries have transformed social institutions, beliefs and attitudes, as well as value systems.

Mathematics and Culture

Obviously, mathematics as a discipline belongs to the technological component of culture. As such, mathematics contributes to the determination of ideological, social, and sentimental components of culture. The common perception of mathematics as neutral with regard to culture runs contrary to the nature and development of mathematics as a product of human culture. Being purely symbolic, mathematics is one of the most powerful technologies. Mathematics as a technology derives its power from the fact that it is detached from any contextual referents and hence is applicable to a multitude of situations and contexts. In addition to impacting culture indirectly through science and technology, mathematics impacts culture (and hence, social organizations, beliefs, and ideologies) directly. It suffices to cite the tremendous impact of Euclid geometry and the positional system of numeration on the development of human culture.

Mathematics Education and culture

Mathematics education is another matter. At the school level, mathematics education may be considered as a sub-culture of the school culture that forms a sub-culture of the home culture. It is often the case that the school culture is in conflict with the out-of-school culture because of different values and technologies. Schools value the condensation of accumulated human knowledge whereas out-of school culture values immediacy, efficiency, and utility. School culture uses symbolic technologies to achieve its goals whereas out-of-school culture is heavily dependent on both symbolic and material tools.

Problem Solving and Computers

Problem solving in school mathematics is driven by two goals: The academic goal inside the school and the application goal outside the school. The academic goal in mathematical problem solving uses symbolic input and technology (mainly algorithmic) with and without the use of computers. Outside school, problem solving requires, among other things, mathematization – the ability to recognize the variables and their inter-relations which bear on the problem and at the same time to translate the problem into symbolic technologies.

The computer technology may have a tremendous impact on mathematical problem solving in academic setting. Schoenfeld (1985) identified four components of problem solving: Knowledge base, heuristics, control, and belief system. Table 1 gives examples of the impact of the computer technology on each of the four components of problem solving. The impact of the computer may be highly positive in academic settings because the former is readily accessible to symbolic input. However, the computer has a very limited role outside the school because the former does not seem to contribute to mathematization. The discrepancy in the nature of problem solving between the school and out-of-school contexts have generated a number of over-generalizations regarding the contribution of problem solving in academic contexts to problem solving in out-of-school contexts. I shall call these overgeneralizations myths and I shall use the word reality to refer to corresponding statements which I consider closer to reality and which are supported by research evidence.

Problem Solving Component	Contribution of the Computer
• Knowledge base	• Dramatic increase in the accessible knowledge base
• Heuristics	• More opportunities for effective use of heuristic: making a table, drawing a graph, …
	• Provides more effective management strategies
• Control	• Develops beliefs that are specific to the context in which computer was used
• Belief system	

Table 1: Contribution of the computer to problem solving

Myths and Realities

Myth one

Identical mathematical problem tasks will elicit the same problem solving strategies across different contexts and technologies.

Reality one

Problem-solving strategies are dependent on the context of the problem, goal and motives of the problem-solver, and the accessible tools.

Illustrative Supporting Example

Using activity theory and its methodology, Jurdak and Shahin (2000) examined the structure of the same activity (constructing solids) in school and workplace (plumbing). Data were collected from a plumber in a workshop and five high school students while constructing a cylindrical container of capacity one-liter and height of 20 cm. The actions of the students were analyzed and compared. Figure 1 presents the structure and nature of the actions of each while solving the task.

Thus, despite the fact that both the students' and plumber's actions had a common intentional aspect i.e. the construction of the task container, they significantly differed in the operational aspect (actions) or the means and concrete conditions (operations) under which such a goal is carried out. First, there is a difference in the motive of the two activities: The production of a concrete object in the course of normal job in the case of the plumber and doing a school task at the request of the teacher in the case of students. Second, the plumbing workshop and the school, in which similar tasks were learned, are two different social-cultural settings. Third, the tools that were available and accessible at the time the task was executed, were different and resulted in different actions. The tools used by the plumber were mostly concrete (hand tools, machines and basic equipment, measuring scales). The students used symbols as a "mnemonic-technical" devices and de-contextualized mediation means to calculate the unknown in the formula. Only after the second intervention, the students shifted to utilizing concrete construction tools that were available in their immediate environment. Fourth, there was an obvious difference in the constraints (operations) under which the task was executed. Whereas the plumber was constrained by the properties of the material he was working with and making the material meet the required specifications, the students were mainly constrained by translating the symbols into physical reality.

Myth Two

The use of technologies with high mathematical power in school mathematics will elicit higher-order reasoning and widen the domain of application of that technology.

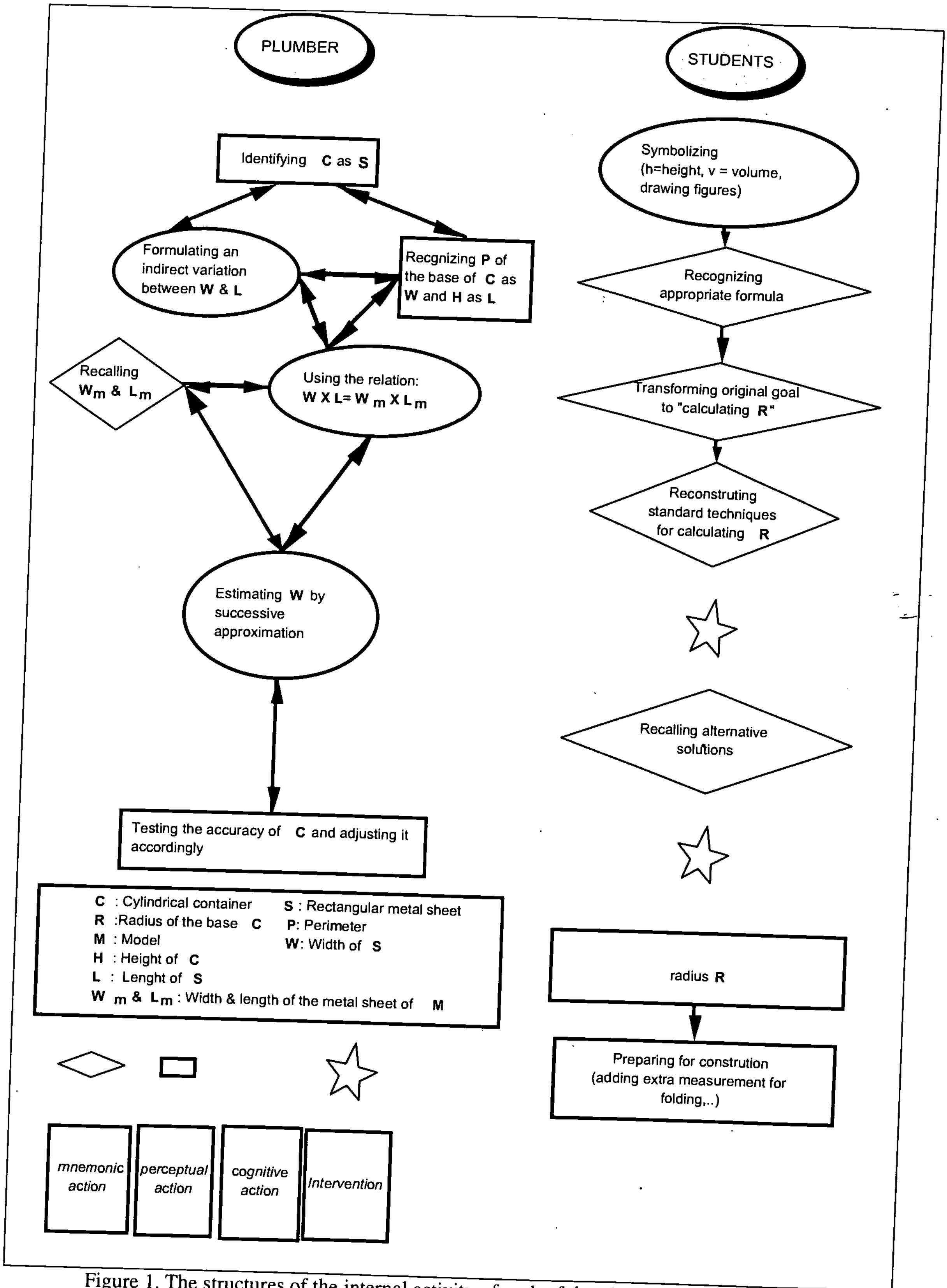

Figure 1. The structures of the internal activity of each of the plumber and the students

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Reality Two

In school mathematics, the use of technology with high mathematical power does not necessarily elicit higher order reasoning or increase the domain of its applicability in problem solving.

Illustrative Supporting Example

Jurdak and Shahin (1999) examined the computational strategies of ten young street vendors in Beirut by describing, comparing, and analyzing the computational strategies used in solving three types of problems in two settings: transactions in the workplace, word problems, and computation exercises in a school-like setting. One episode from the study is given in Figure 2. The results indicate that vendors' use of semantically-based mental computational strategies was more predominant in transactions and word problems than in computation exercises whereas written school-like computational strategies were used more frequently in computation exercises than in word problems and transactions. There was clear evidence of more effective use of logic-mathematical properties in transactions and word problems than in computation exercises. Moreover, the success rate associated with each of transactions and word problems were much higher than that associated with computation exercises.

Transaction context. *In working his way towards finding the retail price of 9 kilos of potatoes, 750 lira/kilo, Ahmed said: "1 kilo for 750 lira then 10 kilos cost 7500 lira so 9 kilos will cost 6750 lira". What Ahmed did was the following: he treated the problem that was originally 750 x 9 into 750 x (10-1) that amounted to 750 x 10 - 750 which was 7500-750 and this gave 6750.*

School context. *In subtracting 250 from 500, Ahmed proceeded mentally: "500 take away 250 there remains 250—it doesn't need calculations". But when asked to perform the subtraction algorithm using paper and pencil starting properly from right-to-left, he said: "O.K, now zero goes down, 0 take away 5 remains 5, 5 take away 2 remains 3 ". He wrote:*

$$\begin{array}{r} 500 \\ -\ \underline{250} \\ 350 \end{array}$$

Then, talking to himself, he said: "How is this? It gave 350? (Pause) ... but 5 take away 2 gives 3 (pause) 350 ? (Pause)...it is right 350". As we can see, whatever the reason, translating from mental to written form did not confirm the correctness of Ahmed's initial solution but only added to his confusion.

Source: Jurdak and Shahin (1999)

Figure2. Episode (Ahmad, 16 years old, attended school until grade 8)

Myth Three

School mathematics can be based *completely* on meaningful experiential learning using a variety of out-of-school technologies.

Reality Three

School mathematics will always include some mathematics that is not meaningful to the students at the time they learn it.

Theoretical support

There are a number of experimental studies which demonstrated the superiority of experiential learning in school mathematics. However, these studies were not based on pure experiential learning but rather on an amalgamation of learning approaches in which experiential learning was dominant. The support against this myth is rather theoretical and practical. According to White (1959), the accumulation of cultural products through symbols is unique to human culture and hence is the basis of human progress. Each human generation builds on the cultures of previous generations. Thus it is not conceivable for youngsters to reconstruct all mathematical knowledge based on experience. Moreover, it is neither practical nor economical for schools as social institutions to afford complete reliance on experiential learning

Concluding Remarks

There is an inherent conflict between mathematics and its pedagogy. In mathematics teaching, we are concerned with the *meaning* of mathematics whereas in mathematics we are concerned with its *power*. Mathematics takes its meaning from the concrete situations it refers to. On the other hand, mathematics derives its mathematical power (symbolic technological power) from being detached from the situations that give it meaning.

Since it is not realistic, and perhaps not desirable, to attach meaning to everything we teach in mathematics, it is less desirable to sacrifice meaning in teaching mathematics at the expense of its power. Hence my call for building bridges between school mathematics and everyday life including the workplace, and between the technological tools of mathematics in school and material tools outside it. Computer technology will do a disservice to problem solving in mathematics teaching if it does not build bridges with problem solving in real life.

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